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Micro Energy Source using WGMs of Wave in Small Scale Optical Device

R. Siriroj[a], N. Thammawongsa[b] and P. P. Yupapin[c]*

[a,c]*Advanced Studies Center, Department of Physics, Faculty of Science, King Mongkut's Institute of Technology Ladkrabang,, Bangkok 10520, Thailand*
[b]*Faculty of Industrial Technology, Udon Thani Rajabhat University, Udon Thani, Thailand*

Abstract

Simulation results of forms of waves in a ring resonator system known as a PANDA ring resonator for coated and uncoated materials have been proposed and discussed. The input waves (lights) can be in the forms of soliton, Gaussian pulses, photon or matter wave. The trapped electron motion around the PANDA ring can also be generated, in which the matter wave concept is formed within the PANDA ring waveguide. From the results, we found that the whispering gallery mode (WGM) can be generated due to coupling effects of the two nonlinear side rings, which have shown many interesting results and aspects, especially for energy applications, which can be fabricated and tested on-chip.

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Keywords: Micro energy device; plasma source; fission energy; antimatter; microjet

1. Introduction

The use of micro device for energy has become the interesting energy device target this day, which has been recognized as a good candidate for new device for energy due the advantages such as small size, light weight, ease to produce, less power consumption and low cost, while the wide application can be addressed. Recently, the use of w*hispering gallery modes (WGMs)* of waves in nature such as electromagnetic wave, sound wave and matter wave has shown the interesting results which can be

* Corresponding author. Tel.: +66-2-3298400 ; fax: +66-2-3298410.
E-mail address: kypreech@kmitl.ac.th

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useful for fundamental studies and applications in optoelectronics and nano-electronics, especially, after the announcement of Nobel Prize 2012 in Physics on the WGMs [1, 2], where the authors have confirmed that atoms can be trapped (stopped) by using the WGM in a microsphere. However, there are two more kinds of devices that can be used to trap light beams (atoms), the use of microcavity arrays performed by Yanik and Fan [3], and a nonlinear microring resonator by Yupapin and Pornsuwancharoen [4] for stopping light. Recently, Ang and Ngo [5] have also done experiment to slowing light using microresonators using a microring system. In this article, a new design of microring resonator device is proposed which can be used to generate four forms of light simultaneously on a chip, whereas the storing and harvesting of trapped atoms/molecules can also be available. The proposed device is made up of silica and ***InGaAsP/InP*** with linear optical add-drop filter incorporating two nonlinear micro/nano rings on both sides of the center ring (modified add-drop filter). This particular configuration is known as a "**PANDA**" ring resonator [6] as shown in Fig.1. Light pulse, for instance, Gaussian, bright and dark solitons is fed into the system through different ports such as add port and through port. By using the practical device parameters, the simulation results are obtained using the **Optiwave** and **MATLAB** programs. Results obtained by both analytical and numerical methods show that many applications can be exploited. In applications, when the practical device parameters are used, then such device can be fabricated and implemented in the near future, which can be useful for energy source devices such as micro plasma, antimatter, misrojet, fission energy sources.

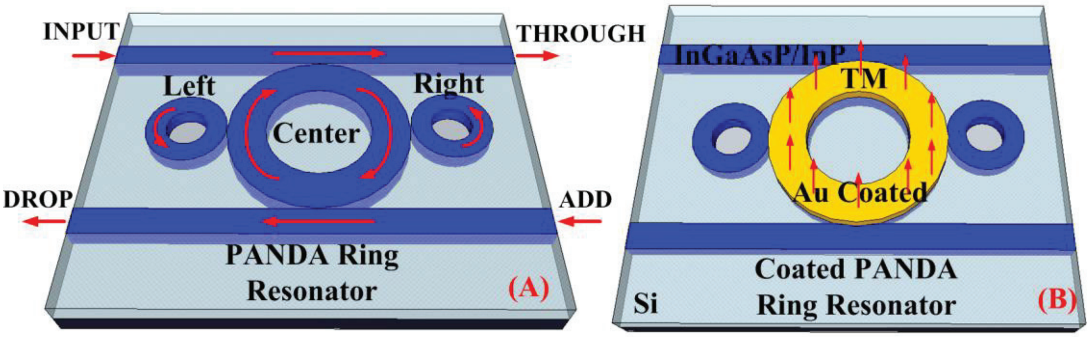

Fig. 1. (A) a conventional PANDA ring planar wave guide was named and designed by Uomwech et al [6] and (B) Gold coated PANDA ring resonator for TM polarized coupling device

The whispering gallery mode result is obtained using the **Optiwave** program as shown in Fig. 2. The ring material is ***InGaAsP/InP***, where the device parameters are given in figure caption. By using the **MATLAB** program, the whispering gallery modes of four state of light i.e. fast, slow, stopping and storing can be generated and controlled simultaneously on-chip as shown in Fig. 3. The storing stage can be seen easily, while the stopping condition can be observed as the following conditions are satisfied: (i) the center signal is lost in time between fast and slow signals or (ii) there is no movement among trapped particles or molecules i.e. the exchange of angular momentum introduces the conservation of angular momentum, where the combination of scattering and gradient forces is balanced under the adiabatic process. The stopping light in term of signal condition can be easily performed using the whispering gallery mode concept, where the fast and slow light can be used as the upper and lower time frames or upper side and lower side peak signals for the storing light at the center as shown in Fig. 3, where in this case the movement (modulated signals) longer than 150 fs, i.e. ms, ns, ps is observed (stopped). The input pulse is a Gaussian pulse with pulse width of 100 fs, where the fast and slow time interval is known, however, the whispering gallery modes can be seen only under the resonant condition.

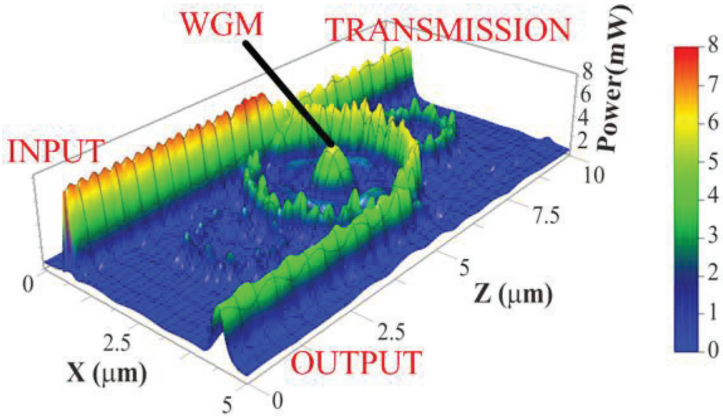

Fig. 2. Result of whispering gallery mode of light within a PANDA ring waveguide InGaAsP/InP, $R_1 = R_2 = 0.775$ μm, $R_{ad} = 1.565$, $A_{eff} = 0.3$ μm^2, $n_{eff} = 3.14$, $n_2 = 1.3 \times 10^{-13}$ cm^2/W , $\kappa_1 = \kappa_2 = \kappa_3 = \kappa_4 = 0.5$, $\gamma = 0.01$, $\lambda_0 = 1{,}550$ nm

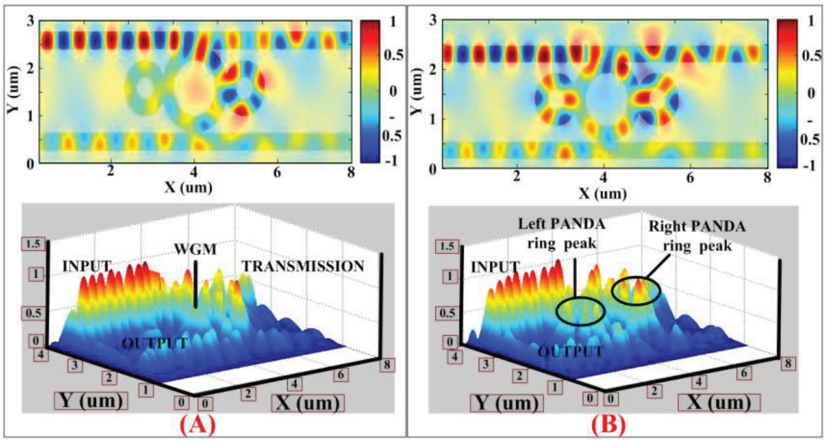

Fig. 3. Stopping and storing light simultaneously detected using a PANDA ring, where (A) Center ring, (B) Side rings

The use of light trapping probe for atom/molecule trapping and transportation (dynamically trapping) can be formed with wide range of applications. In this case the modulated signal is required to switch off the whispering gallery mode power via the add port, where atoms/molecules at the device center can be trapped and transported along the wave guide by the surface plasmon tweezers as shown in Fig. 4. The dynamic tweezers are generated by a PANDA ring, whereas in practice, particle angular momentum can be introduced by a metal coating material on the waveguide surface or combining the external modulation via the add port, which can be used to trap and transport atom/molecule to the required destination when the gradient force is greater than the scattering force along the waveguide. From the above reasons, we found that the WGM of light can be easily formed by a microring resonator

[7] or nonlinear coupling effects to the center ring of a PANDA ring [8]. In Fig. 5, the WGM and leaky modes are generated by a PANDA ring which can be formed in the same ways for large scale motion. Thus, the use of **WGM** for large scale motion can be useful, for instance, in the large scale devices(circuits), where in this case the matter wave(wave-particle duality) can be formed by the Moon orbital motion around the Earth, which can be useful for Earth disaster investigation and prediction. Another application is the atomic modulation can be formed by using the WGM of light in a PANDA ring as shown in Fig. 6, where the atoms are trapped and storage at the center ring, while the external modulation to the trapped atoms can also be available.

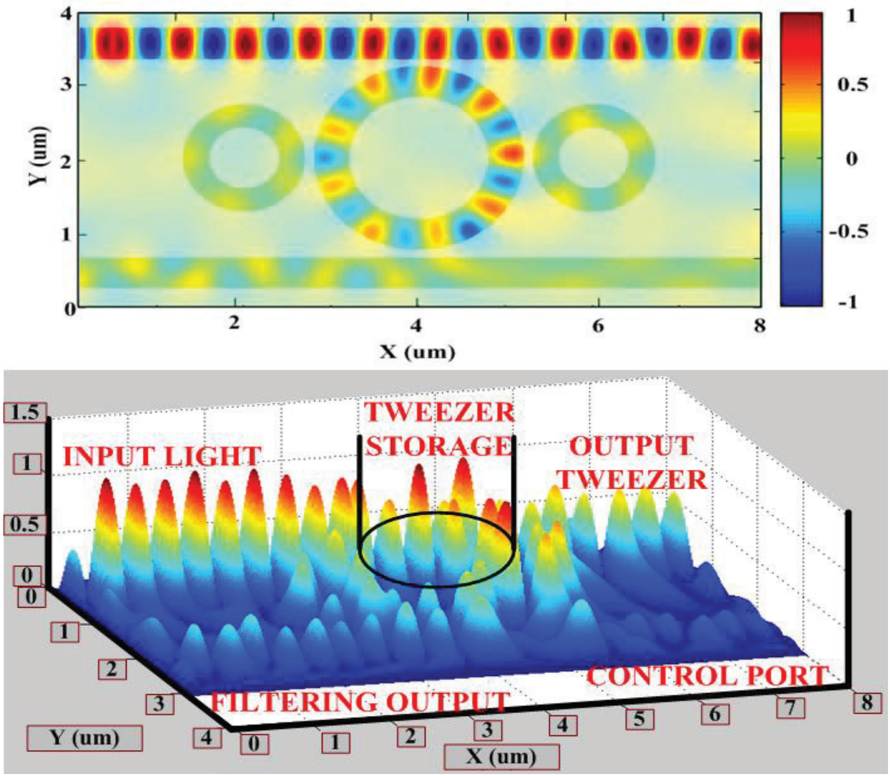

Fig. 4. Dynamic tweezers are generated by a PANDA ring and transmitted via a Through port for atoms/molecules harvesting and transportation

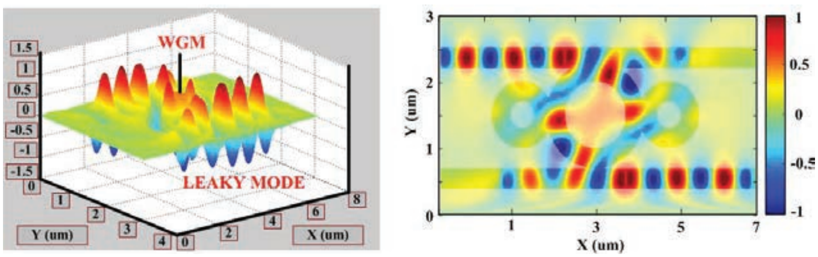

Fig. 5. WGMs and leaky modes generated by a PANDA ring

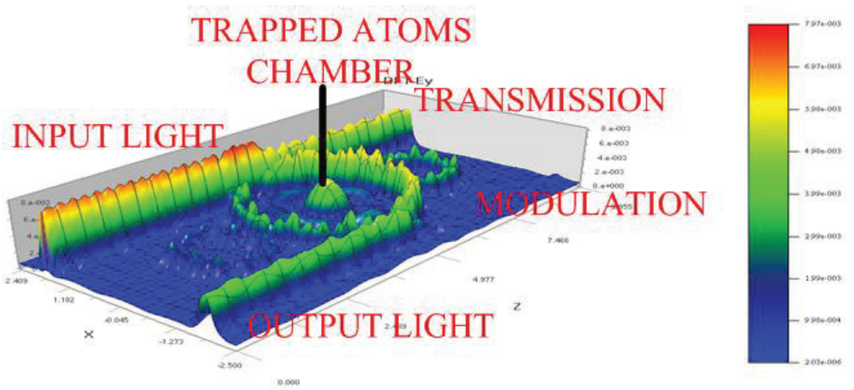

Fig. 6. Schematic diagram of trapping and modulating atom by light

2. Atom Trapping for Energy Source Applications

To perform the experiment that atoms can interact with light one of the techniques uses a standard magneto-optic trap (MOT)[11], where analysis of the cold collision measurements performed in a high-gradient magneto-optical trap with a few trapped Cs atoms. The net result is a cloud of cold, confined cesium atoms inside a vacuum chamber, providing a convenient initial condition for optical-lattice experiments. While in the optical lattice, the trapping fields are extinguished so that they do not interfere with the atomic dynamics in the lattice.

The primary challenge in observing dynamical tunneling experimentally lies in the preparation of the initial state. In brief, this state-preparation process involves trapping and cooling the atoms in a standard magneto-optic trap, applying laser light to polarize the atomic spins into a state that is insensitive to magnetic fields, driving two photon transition to select out the coldest 0.3% of the atoms, and then manipulating the atoms with the optical lattice to produce a nearly minimum uncertainty wave packet localized on one of the stability islands. Small scale optical device can be used as an electron correlation generation source, in which electrons across the gap are driven by quantum tunneling and required a new description of non-local transport, which is crucial in nanoscale optoelectronics and single-molecule electronics.

In our FDTD simulation, the perfectly matched layer (PML) absorbing boundary conditions have been applied by Berenger [12] and Yee scheme [13], which absorbs the electromagnetic wave without any reflection at the computational boundary. A 100 fs-Gaussian pulse modulated by a 200THz carrier is exited. The vertical waveguide thickness and material composition is accounted by computing the effective refractive index n_{eff} for the fundamental mode at $\lambda = 1.55\mu m$. In the vertical direction, each waveguide structure is $0.45\mu m$ thick, vertical core thicknesses of $0.3\mu m$ to $0.5\mu m$, n_{eff} is between 3.2 to 3.4 , in which the parameters are obtained by using the practical material parameters of ***InGaAsP/InP***. Therefore, the waveguide core n=3.14 is bordered on each side by air n=1. The parameters for add-drop optical multiplexer and both nanorings on the left and right hand sides of the PANDA ring are set at $R_l = R_r = 0.75\mu m$ and radius of the center ring is $R_{ad} = 1.5\mu m$. The coupling coefficient ratios are $\kappa_1 = \kappa_4 = 0.5$, $\kappa_2 = \kappa_3 = 0.4$, effective core area of the waveguides is $A_{eff} = 0.25\ \mu m^2$, and waveguide loss coefficient is $\alpha = 0.1$ dB/mm. When gold material is coupled as a function of frequency by coating on the waveguide as shown in Fig. 1, the free carrier concentration of gold is $N \approx 6\times10^{22} cm^{-3}$ and the plasma frequency is $\omega_p / 2\pi \approx 2\times10^3$.

In this work, the whispering gallery modes can be generated and trapped particles/antiparticles within a PANDA rings as shown in Fig. 7, where the tunneling particles/antiparticles can be generated when the particle energy is greater than the trapping potential well as shown in Fig. 8. By using the **MATLAB** program, the whispering gallery modes of tunneling particles/antiparticles can be generated and controlled. The tunneling particles/particles can be confined by the WGMs at the center, which can be used as particle source for various applications as shown in Fig. 9 and 10. The interesting applications aspects such as microplasme source, fission energy source, particle and antimatter energy source and microjet system are very convincing energy sources that will be our future research works.

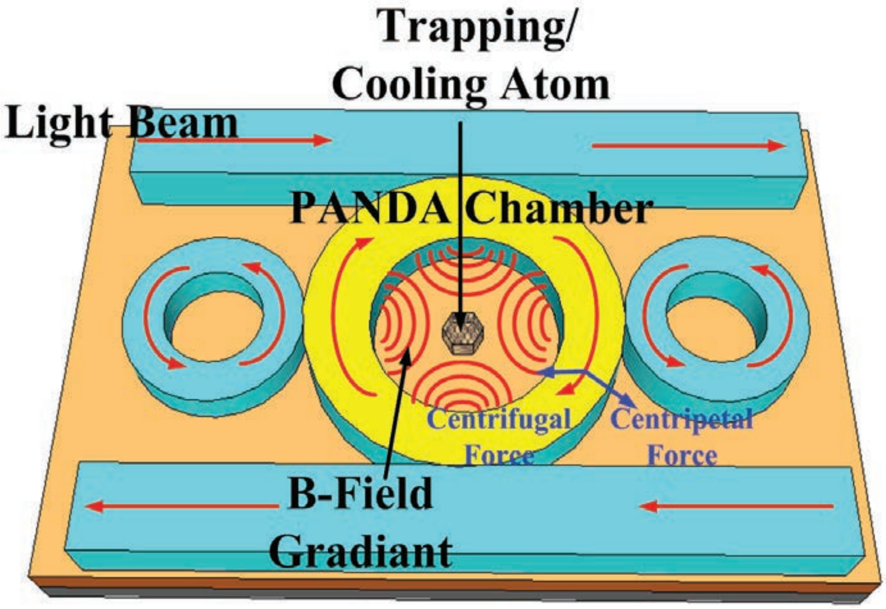

Fig. 7. PANDA chamber for particle/antiparticle trapping and storage under
(i) centripetal and centrifugal forces, (ii) WGMs

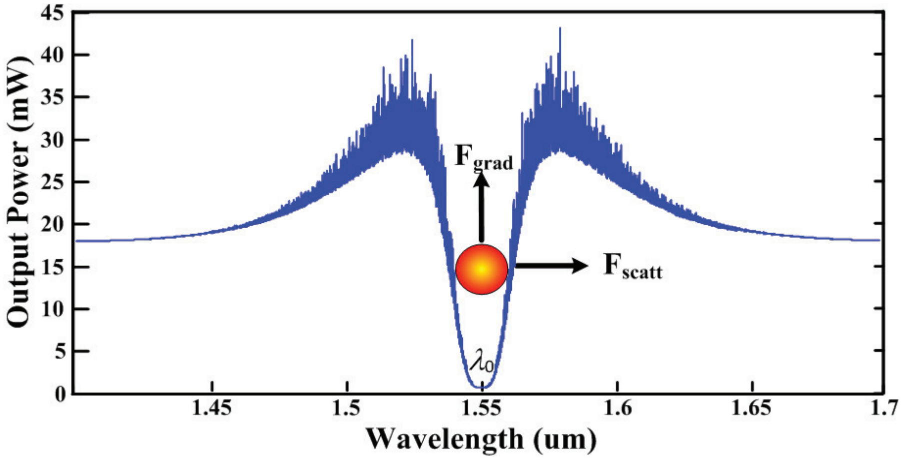

Fig. 8. Particle/antiparticle can be trapped by a potential well within a PANDA ring waveguide, where F_{grad}: Gradient force, F_{scatt}: Scattering force

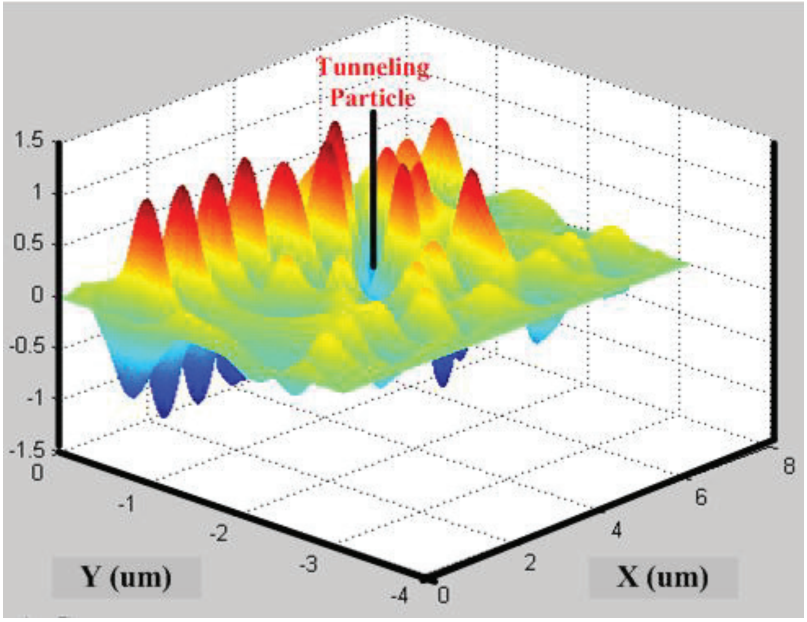

Fig. 9. Dynamic tunneling particles/particles, where X and Y: two dimension scale

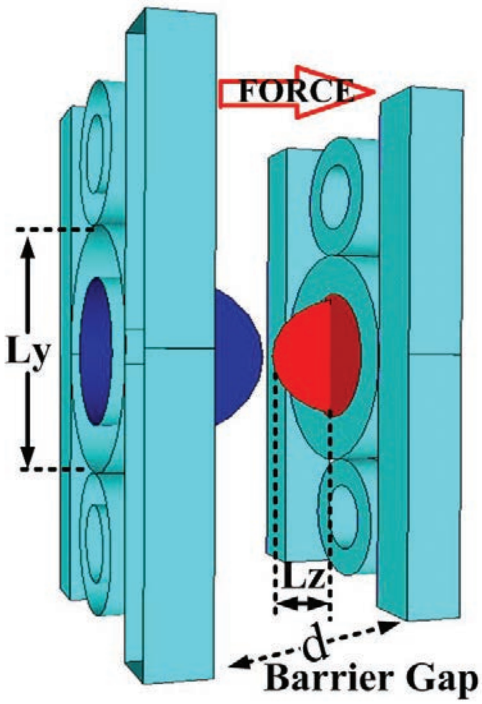

Fig. 10. WGMs switching control for fission and antimatter energy use, where Ly, Lz : WGMs dimension, d: Device(Barrier) Gap

3. Conclusion

Forms of light in a PANDA ring resonator with or without coated material can be manipulated, and it can be observed that the two nonlinear side rings have shown the interesting results and aspects. The input light can be in the forms of soliton or Gaussian pulses. The use of photon or matter wave as input is also possible. Particularly, an interesting aspect can also be formed by using the trapped particle, in which the matter wave concept can arise within the PANDA ring waveguide. The expected output light can be in the forms of surface plasmon, potential wells, leaky modes, whispering gallery modes, matter wave and photons (particles). The use of nonlinear Schrodinger equation can also be available, where in this case the propagation of light being treated as a particle (photon) within the PANDA ring, in which the tunneling effects of particles can be performed and investigated, which can be useful for energy source applications.

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